Computer Communications 71 (2015) 84–96

Contents lists available at ScienceDirect

Computer Communications

journal homepage: www.elsevier.com/locate/comcom

# CSAR: A Content-Scent based Architecture for Information-Centric mobile ad hoc networks

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ARTICLE INFO

*Article history:*
Received 23 September 2014
Revised 6 April 2015
Accepted 22 September 2015
Available online 9 October 2015

*Keywords:*
Future Internet
Information-Centric Networking
Mobile ad hoc networks
Routing scheme
Content-scent

ABSTRACT

Information-Centric Networking (ICN) is regarded as one of the representative network architectures of Future Internet. In this paper, an information-centric architecture called Content-Scent based Architecture (CSAR) will be proposed for mobile ad hoc networks. In CSAR, each content has its special content-scent and can be found by tracing the scent it spreads over the network. The content-scent has the property similar to the natural scent that can spread over air, mix with other scents, decay with distance and time, and strengthen with fresh supplement. Using this property, scent-based routing and reliable content delivery functionalities are provided for the mobile ad hoc environment. Simulation results show that CSAR has an efficient route discovery procedure with less routing overhead and better in-network caching for the mobile ad hoc networks.

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## 1. Introduction

A mobile ad hoc network (MANET) [1] is a collection of mobile nodes without fixed infrastructure. It is a multi-hop wireless network, in which mobile nodes can be either end points or routers. MANETs can be established quickly at emergency scenarios, such as, battlefield communications and disaster relief.

Inherited from wired network protocol stack, mobile nodes are usually assigned IP addresses. A single determined path which contains a series of nodes between source and destination nodes is set up by IP based routing protocols. However, IP based routing solutions are not suitable for the wireless networks because of their high degree of topological dynamics [2]. It is difficult to maintain IP addresses for mobile nodes. And point-to-point transmissions at MAC layer in these solutions do not utilize the broadcast nature of the wireless environment.

TCP/IP architecture was designed over 40 years ago with certain design principles [3]. New functionalities and services are difficult to add to the network core, which is called the ossification of Internet [4]. Hence, there are many clean slate redesign architectures for Future Internet recently. Information-Centric Networking (ICN) [5–8] is one of the most prominent architectures among them. An information-centric network [9] is a communication network in which content is treated as the first-class citizen rather than host. Although many ICN architectures are designed for wired networks originally, they can be particularly beneficial in wireless environment, since it does not need to maintain end-to-end connections. The recent years' works [10–12] have shown that ICN idea can be applied into the design of MANET architecture.

Based on ICN architecture, a Content-Scent based Architecture (CSAR) is proposed for mobile ad hoc networks. CSAR assumes that content has its special content-scent. This makes it possible that consumers find a content by tracing its content-scent over the network. The content-scent is assumed having the property similar to the natural scent that can spread over air, mix with other scents, decay with distance and time, and strengthen with fresh supplement. The spreading nature is more appropriate to the broadcast environment and allows content providers to publish contents by broadcasting content-scents over the network. The mixing nature provides a mechanism to store a lot of content-scents in a compact data structure, and to reduce size of routing tables. This reduction is extremely important for the information-centric networks (including wired and wireless networks) because the amount of contents in the networks is huge. Finally, the decaying and strengthening natures are most suited for mobile ad hoc environment.

The main contributions of this paper include:

- A Content-Scent based Architecture is designed for mobile ad hoc networks. It provides routing and reliable content delivery functionalities.
- Content-scent of a content is defined and the mixed content-scents of different contents are stored in a compact data structure called Scent-Table. In addition, a content-scent emitting and attenuation mechanism for content-scents is proposed.

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http://dx.doi.org/10.1016/j.comcom.2015.09.024
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- According to the content-scent emitting mechanism, an in-network caching mechanism for content is designed in the procedure of data delivery.

The rest of the paper is organized as follows. In Section 2, we present the related work. Then, content-scent and Scent-Table are defined in Section 3. Broadcast-based and scent-based routing principles are presented in Section 4. Detail of procedures in CSAR is presented in Section 5; the architecture is evaluated and results are showed in Section 6; in Section 7, we conclude the paper.

## 2. Related work

Traditional IP based routings for mobile ad hoc networks can be classified as: *proactive*, *reactive* and *hybrid* approaches. *Proactive* routing protocols [13,14] leverage periodic network flooding for the advertisement of all available destination nodes. It keeps an up-to-date topological structure for the entire network. These protocols are only applied to small scale networks due to the periodic network flooding. Instead of maintaining up-to-date routing information at all of the nodes, *reactive* routing protocols [15,16] establish routing paths in an on-demand manner. These protocols need less routing control overhead than proactive approaches, and they are in general more scalable. AODV [15] is a classic reactive routing algorithm for mobile ad hoc networks. It uses an on-demand approach for finding routes, that is, a route is established only when it is required by a source node for transmitting data packets. Because AODV does not require global periodic routing advertisements, the demand on the overall bandwidth available to the mobile nodes is substantially less than in proactive protocols that do necessitate such advertisements. A disadvantage of this approach is a possible large delay from the moment the route is needed until the time the route is actually acquired. *Hybrid* approaches [17,18] have the former two components in order to combine the best of both routing ideas.

However, these IP based routing schemes do not fit the wireless environment well [2] because, for examples, IP assignment and management are difficult and point-to-point transmissions at the MAC layer do not utilize the broadcasting in nature property in wireless ad hoc networks.

There is a new design direction for wireless networks recently, which are information-centric mobile ad hoc networks. Listen First, Broadcast Later (LFBL) [19] is a topology-agnostic information centric forwarding protocol under high dynamics. It is composed of two phases: a request phase and a data phase. A request packet is flooded through the network in the request phase. Intermediate nodes overhear packets to discover if they are eligible forwarders. Receivers make the forwarding decision and only keep a minimal amount of state. A distance based forwarding procedure with collision avoidance is presented in the data phase. Simulations show LFBL significantly outperforms AODV [15] under highly dynamic environments.

In [20], the authors propose an energy-efficient content retrieval scheme for mobile cloud to decrease the traffic overhead of the Interest dissemination and save the transmission energy. A direction-selective forwarding scheme for the Interest dissemination phase is proposed. The experiment results show that this content retrieval scheme is capable of retrieving any content in the large scale MANET with high hit rate and low traffic overhead.

CCN (also known as NDN [6]) is a representative ICN architecture in recent years. It contains three components: content name advertisement by some routing protocols (an ongoing research) to build FIB tables in the network, an interest packets flooding phase to search the required content, and a data comes back procedure. In [28], the authors propose NAIF, a named data MANET forwarding protocol aiming at reducing the high overhead of NDN forwarding design. Work [21] is a survey which focuses specifically on the CCN paradigm, and it provides a comprehensive overview and a clear identification of the applicability, potentialities, weaknesses and future challenges of this paradigm in wireless networks. Works [10–12,22,23] are extended from CCN architecture for mobile ad hoc networks.

In [12], CCN is implemented on emergency wireless ad hoc environments. Interest aggregation and collision avoidance mechanisms are added to cope with the disruptive networks. Its performance benefits and superiority over Optimized Link State Routing Protocol (OLSR) [14] is demonstrated. In [22], the authors design a set of analytical to evaluate performance of several candidate routing protocols for content-centric MANET, including reactive flooding, proactive flooding, and geographic hash tables. A surprising result of this analysis is the competitive performance of unstructured flooding compared to more sophisticated techniques. LACMA [23] is a Location-Aided Content Management Architecture for a content-centric MANET. It tries to keep a content copy within a specified geographic boundary based on the location information make available by GPS and by proactively replication the content as necessary.

CHANET [10] is a content-centric mobile ad hoc network. It built on a connectionless layer designed on top of IEEE 802.11 protocols to provide content-based routing. In CHANET, interest and data packets are broadcasted, and nodes take local forwarding decisions based on packet overhearing. The same authors design enhanced architecture called E-CHANET [11] based on [10]. E-CHANET implements routing, forwarding, and transporting functions on top of the IEEE 802.11 wireless access. Interest and Data forwarding exploits a packet suppression technique to avoid redundancy and to control scalability, and ad hoc designed mechanisms to cope with node mobility. In addition to the basic routing and forwarding functionalities from CHANET, a new content-centric transport function which regulates the Interest transmission rate from mobile consumers is designed.

Simulated annealing [27] is an optimization procedure, aiming at converging to the global optimum. To reach the global optimum, it accepts a worse solution with a slow decrease probability at each iteration step. In contrast, CSAR does not accept a worse solution in the procedure of rebroadcasting request packet, and accept either the global optimal or a local optimal solution, because the content can be provided by any provider node.

## 3. Content-scent and Scent-Table

In CSAR, content has its special content-scent, and mixed content-scents of different contents can be stored in a Scent-Table. In this section, we define content-scent, Scent-Table, and operation of Scent-Tables.

Our purpose is to map each content name to its content-scent, and extend the name-based routing of ICN to a scent-based routing. The content-scent strength arrived at a node is related to the capability of the original provider node and the distance away from it. The capability of the original provider node indicates the ability of the provider to supply this content, such as processing capacity and bandwidth. The distance between nodes can be defined, such as, geographic distance, hop count, transmission delay and link cost etc.

Suppose a content in node $A$ has a name $id$. If node $B$ receives the scent packet emitted from node $A$, then the Content-Scent Strength (CSS) emitted to node $B$ is defined as:

$$\mathrm{CSS}(id)_{A\to B} = Q_A / D^2_{A\to B} \tag{1}$$

where $Q_A$ is the capability of node $A$ providing the content, and $D_{A\to B}$ is the distance from node $A$ to node $B$.

We define a compact data structure, called Scent-Table, to record mixed content-scents or content names. As shown in Fig. 1, a Scent-Table contains a set of vectors $\{D_1, D_2, \ldots, D_k\}$ and the corresponding hash functions $hash_i()$, for $i = 1, 2, \ldots, k$. Each vector $D_i$ has $M$ components: $D_{i,j}$ ($i = 1, 2, \ldots, \mathrm{k}, j = 1, 2, \ldots, M$). The Scent-Table can be real or binary depending on requirements. In its real number form where $D_{i,j}$ is a real number, it can record the mixed content-scents of contents. The content-scent strength of each content can be obtained

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